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Participatory plant breeding's contribution to resilience and the triple bottom line of sustainability--healthy ecosystem, vital economy, and social inclusion

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by

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PURPOSE

This study is an analysis of the emerging participatory plant breeding (PPB) approach to organic seed development for its impact on the triple bottom line of sustainability-- healthy ecosystem, vital economy, and social inclusion. The study utilized the following working definition of PPB: "the involvement of end users (and sometimes other actors) in any number of the full range of genetic improvement activities. This includes setting breeding goals, creating genetic variability, selecting within variable populations, evaluating and selecting experimental varieties, releasing and popularizing new varieties and multiplying and distributing seed" (PBWG, 2000). The nature of the topic entails a qualitative framework analysis integrating the principles of ecological economics, resilience, and sustainable community development into the community capitals framework.

This analysis will provide evidence that PPB is essential to the development of genetically diverse, open-source seed systems necessary to provide the adaptive capacity to enable our food system to respond to ecological, social and economic changes. This is vital to seed sovereignty and food security. It is necessary to reinvent and reinvigorate public plant breeding systems to support continued development of PPB partnerships and open-source germplasm and seed systems.

KEY FINDINGS

- PPB democratizes the plant breeding process by incorporating a diversity of perspectives through strong feedback loops, providing the social learning mechanisms necessary for a responsive and resilient seed system capable of adapting to changes in both the agroecological and socio-economic environment.
- Resilient and adaptive farming systems require open-source germplasm and seed access to provide the genetic diversity necessary for the co-evolution of the agroecological and socio-economic aspects of agroecosystems.
- PPB is a form of community development which mobilizes and integrates human, natural, and social capital, fostering: *socially-inclusive* plant-breeding and seed systems; *ecological health* and resilience through greater agrobiodiversity and adaptability; and *economic vitality* through reduced farm input costs, greater farm outputs, enhanced viability of existing organic seed companies, and the opportunity for growth of local and regional seed systems. PPB partnerships directly address the triple bottom line of sustainability.

THE PROBLEM STATEMENT

Organic producers are highly dependent upon plant varieties bred for industrial agriculture (Lammerts Van Bueren et al., 2008, Colley & Dillon, 2004). Industrial agriculture is based on input intensive, genetically uniform varieties and monoculture production systems. The seed is protected by intellectual property regimes resulting in exclusive seed systems, corporate control and the narrowing of agrobiodiversity and varietal choices. The "green revolution" breeding goals of maximum yields and uniformity are not well suited to variable, stressful, or challenging environments (Wolfe et al., 2008).

Certified organic seed is often supplied by simply multiplying commercially available varieties using organic production practices. There is little or no selection work for traits of interest to organic farming and marketing systems, including adaptation to local climatic and soil conditions, weed competition, durable disease and pest resistance, beneficial soil microorganism - root interactions, nutrient uptake, yield stability, and nutritional and quality traits (Colley & Dillon, 2004; Lammerts Van Bueren et al, 2008).

A new orientation in plant breeding for agroecological systems must integrate ecological adaptation and adaptation to farm management practices to provide appropriate genotypes and yield stability (Dambroth & Bassam, 1983). The variability of organic farming systems and environments coupled with the diversity of farmer's needs translates into a sizable challenge for plant breeders, a lack of interest from the formal seed sector, and a lack of adapted varieties (Murphy et al., 2005; Desclaux, 2005). Current trends towards a more local, diverse, and sustainable agriculture require linkages between plant breeders and farmers "to assure that a new set of goals and methods is taken up to meet the needs of this new, developing agriculture," (Sligh & Lauffer, 2003, p. P1).

INTRODUCTION

The passage of the Bayh-Dole Act in 1980 allowed research and inventions funded by public dollars to be patented and licensed to private companies. Decreased funding for basic public plant breeding under USDA's National Research Initiative has resulted in the erosion of public breeding programs (Taxler et al., 2005) coupled with a lack of adequate funding and infrastructure for germplasm conservation (Jahn, 2007; Sligh & Lauffer, 2003). New intellectual property regimes based on the patenting of genes and genetic traits have fueled:

- an increasingly restrictive flow of proprietary germplasm (Falcon & Fowler, 2002; Kloppenburg, 1988, Kloppenburg, 2008)
- the loss of the farmers right to save, use, barter and sell seeds reproduced on their farms (Vía Campesina, 2008; Kloppenburg, 2008; ETC Group, 2008)
- massive consolidations in the seed industry (ETC Group, 2008; Howard, 2009). [See Appendix A. Figure 8. pg. 44.]

These changes have resulted in losses of cultural, social, human, and natural capital, including loss of public plant breeders (Taxler et al., 2005), regionally-based small seed companies (Fernandez-Cornejo, 2004; Hendrickson & Heffernan, 2003) and commercially available varieties. "In recent years, due to a pronounced consolidation of the global seed industry, the range of variety choices has dwindled; some of the very best varieties for organic growers are no longer available" (Jahn, 2008; Colley & Dillon, 2004).

As the seed industry has consolidated into a system dominated by multinational biotechnology companies, many seed markets are underserved (Henning & Jahn, 2003). Changes in university funding have precipitated a shift away from public seed breeding efforts to an increasing focus on genomics and on developing proprietary breeds profitable to industry research partners (Colley & Dillon, 2004). One plant breeder interviewed in this study stated, "One of the downsides of the current system is we almost never deal with those folks looking for specialty things." Another plant breeder participant concurred, adding, " It is fair to say most seed markets in the United States are underserved. One of those really important ones [is] organics." Organic seed companies have sprung up in response to these markets but are predominantly small with few resources for breeding work. One plant breeder stated that most organic seed companies have never accessed the traditional research establishment.

Conventional agricultural systems are fostered by land grant universities (LGUs), USDA, and increasingly by multinational agribusiness corporations (Lyson & Green, 1999; Fitzgerald, 1990). Organic food sales represent nearly 4% of the domestic food retail market. Despite this, United States Department of Agriculture's (USDA) funding for organic research, education, and extension (REE) is only slightly over 1% of total USDA-REE expenditures (OFRF, 2008b). Organic agriculture relies on knowledge-based, management-intensive approaches for its success. The lack of research funding dedicated to organic agriculture systems is severely detrimental (Lipson, 2007).

Plant breeding for conventional agriculture is a process by which breeders collect and evaluate germplasm at centralized experiment stations under ideal, controlled environments. The breeder selects parent material based on the breeding program's priorities, making crosses of select materials. The breeder then selects lines to be released and distributed to farmers (Chiffoleau & Desclaux, 2006). This process is best suited to farming systems similar to those employed at the experiment station (Sperling et al., 2001).

The assumptions made by conventional plant breeding programs considered inappropriate to organic breeding systems include: selection under optimum or near optimum conditions, the necessity and desirability of genetic uniformity, the priority status of maximum yield, and involving end-users only in the final testing (Lammerts Van Bueren et. al, 2008). The current seed system focuses on maximizing scale and return on investment with little attention to ecological principles of appropriate scale, just distribution, and efficient allocation.

The United Nations Millennium Ecosystem Assessment Synthesis Report (Sarukhán & Whyte, 2005) documents the loss of both species diversity and genetic diversity. The underlying causes of this loss of diversity consist of a complex mix of policies, practices, and pressures for economic and agricultural growth, as well as demographic changes and inequities in the control of resources (Thrupp, 1998). The loss of biodiversity [diversity of organisms/species within an ecological system] and genetic diversity [diversity within species] may contribute to an ecologically brittle system highly vulnerable to pests and diseases (Holling et al., 1998).

Alternatives

Agroecosystems are co-evolving ecological and socioeconomic systems (Altieri, 2002) comprised of all domesticated plants and animals utilized to produce agricultural products and the people who husband them (Conway, 1987; Conway and Barbier, 1990). They are "the products of human communities mediated by culture and technology" (Flora, 2001, pg. 5). Organic agriculture is defined as "a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved" (IFOAM, 2005). Organic agriculture is an agroecological and socioeconomic production system based on enhancing sustainability.

Walker and Salt (2006) state that resilience is the key to sustainability. Resilience is the ability of a system to absorb disturbances or changes without crossing a threshold, retaining its basic function and structure (Holling, 1973; Walker et al., 2002), opportunities for innovation and renewal (Berkes & Folke, 1998), and its ability to provide needed goods and services (Walker & Salt, 2006). Walker and Salt (2006) propose a resilience framework based on three concepts:

- We are all part of one interlinked social-ecological system
- Social-ecological systems are complex, nonlinear, adaptive systems
- Resilience is the key to sustainability

Sustainability entails investing resources in the development of forms of capital that do not deplete other forms (Flora, 1998). Organic agriculture's principle of ecology reiterates this principle of sustainability states that organic agriculture should strive for ecological balance through the design of its farming systems, maintaining genetic and agricultural crop diversity (IFOAM, 2005).

Complex, adaptive systems have independent and interactive components with a multitude of feedback loops, selection pressures, and constantly emerging variations and novelties. This emergent behavior cannot be predicted by linear cause and effect relationships and by understanding the component parts (Levin, 1998). Changes in one component or a shock to the system may push the system across a threshold, reconfiguring the system (Walker & Salt, 2006). Being able to recognize thresholds and the need for adaptive change increases the likelihood of reorganizing systems gracefully, minimizing system collapse and the loss of social, financial, human, and natural capital (Ibid.). A critical question for scientists is 'whether there are critical thresholds at which loss of biodiversity disrupts ecosystem functions and services?' (NERC, 2009).

Dependence on relatively few crops and varieties has increased the genetic vulnerability of agricultural systems (Kontoleon et al., 2009). Biodiversity enhancement practices are commonly used in organic farming systems (Thrupp, 1998). The literature documents beneficial effects of increased crop species diversity on agroecosystems, including increased plant biomass (Tilman et al., 2006; Naeem, 2009) and increased productivity (Giller et al., 1997; Thrupp, 1998; Naeem, 2009). Increased crop diversity provides greater potential for growing more adapted species (Tilman et al., 2005) while a diversity of traits and characteristics enhances the ability to respond to environmental stresses including invasive species and plant pathogens (Sala, 2000; Giller et al., 1997; Naeem, 2009). Higher levels of crop genetic diversity reduces yield variability and risk of crop failure (Widawsky & Rozelle, 1998; DiFalco & Perring, 2005; DiFalco & Chavas, 2006). Agrobiodiversity provides stability (Altieri, 1987; Naeem, 2009) and resilience by buffering the negative environmental effects associated with climate change (DiFalco & Chavas, 2006).

Incorporating ecological and socioeconomic systems into plant breeding systems for organic agriculture, which is inherently knowledge intensive, context specific, and place-based, requires a system of PPB (Pretty, 1995; Warner, 2006). PPB provides a decentralized, social learning model to generate, improve and supply a diversity of ecologically and economically viable crops (Lammerts Van Bueren & Struik, 2004; Chiffoleau & Desclaux, 2006). Integrating a plant breeder's formal knowledge with the farmer's knowledge about their management systems, agroecosystems, and market demands will require "new communities of practice" (Kirschenmann, 2007). A holistic knowledge model acknowledges both farmers' and scientists' knowledge of plant breeding as grounded in objective observations of reality integrated with intuition, skills, empirical data, theory and values (Soreli et al., 2002).

Involving local people in managing the resilience of social-ecological systems supports adaptive learning, generating responsiveness and success in dealing with current and future needs (Walker & Salt, 2006). Ethnobotanist, Gary Nabhan (2009), asserts that it was this locally bred diversity that geneticist, Nikolay Vavilov (1887- 1943) recognized as the main buffer against famine. Nabhan makes the case that it is the main buffer against potential global famine in our own time. PPB redefines end-users of newly developed varieties as partners in resilience selection and management. The goals of PPB are to:

1) provide plant varieties suitable to agroecological farming systems

2) encourage in situ maintenance of diverse plant populations adapted to local environments (Berg, 1995; Ceccarelli & Grando, 2002), enhancing agrobiodiversity (Witcombe & Virk, 2001) and resilience (DiFalco & Chavas, 2006; Walker & Salt, 2006)

3) empower farmers/rural communities (Desclaux et al., 2007; Weltzien et al., 2000)

Participation is a means to an end, rather than an end in itself (Morris & Bellon, 2004). The process can be *formal-led* (scientists inviting farmers' participation), or *farmer-led* (farmers inviting scientists' participation). Sperling et al., (2001) details three forms of interaction: *consultative* or information sharing, *collaborative* or task sharing, and *collegial,* sharing responsibility, decision-making, and accountability. PPB projects can also differ in the stage of the plant breeding process participation occurs. These variables translate into a number of PPB models from traditional farmer-breeding to "scientific" plant breeding (see Table 1).

Table 1. Models of PPB; F = Farmer; S = Scientist (Morris & Bellon, 2004)

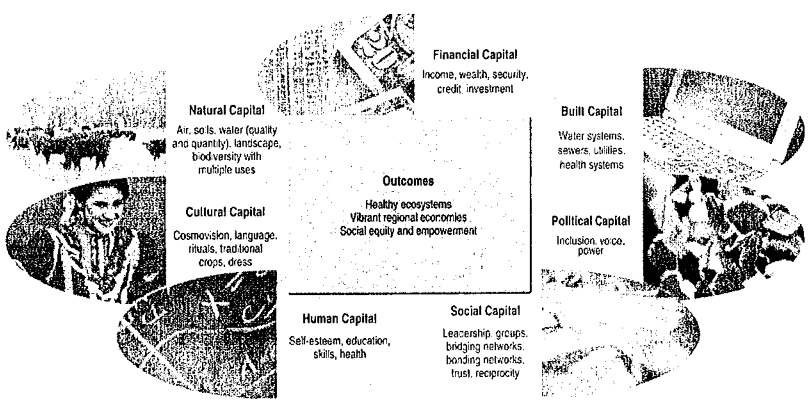
	F	S	F	S	F	S	F	S	F	S
Selection of source germplasm	*		*	*	*	*		*		*
Trait development (pre-breeding)	*		*	*		*		*		*
Cultivar development	*		*	*		*		*		*
Varietal evaluation	*		*	*	*	*	*	*		*
	Model 1: Traditional farmer breeding		Model 2: Complete participatory breeding		Model 3: Efficient participatory breeding		Model 4: Participatory varietal selection		Model 5: "Scientific" plant breeding	

METHODOLOGY

This study utilized the asset-based approach of Appreciative Inquiry (AI) to analyze the social learning process of PPB and its potential to contribute to sustainability. AI, an asset-based approach to community development, purports that inquiry and change happen simultaneously; what we study becomes the shared reality and the direction of change and the questions asked plant the "seeds of change" (Ashford & Patkar, 2001, p. 42). A positive focus causes people to anticipate good things. By focusing on past success, assets, and what worked well, people can carry successes into the future (Ashford & Patkar, 2001).

The interviews were structured using the *Community Capitals* (CC) framework. The CC framework includes seven capitals, which are interrelated (see Figure 1). At the intersection of those overlapping capitals is a healthy ecosystem, vital economy, and social inclusion-- the triple bottom-line of sustainability (Flora & Flora, 2008). "When… resources, or assets, are invested to create new resources, they become *capital*" (Ibid., p. 17). Healthy, sustainable communities pay attention to all seven CCs (Emery, Fey, & Flora, 2006). The CC framework was utilized in this study to gain an understanding of the resources that were mobilized, the effect the project had on the building of CCs, and how the project contributed to sustainability.

Figure 1. Community Capitals Framework (NCRCRD, 2005)



Theory triangulation was employed using the *Resilience* framework (Walker & Salt, 2006) to evaluate the effect of PPB projects on agroecological sustainability and *Latour's Circulatory System of Science* (Warner, 2006) to assess social capital and feedback loops built by PPB partnerships. Finally, the social learning process was examined applying the *Learning Approach* framework (Lightfoot et al., 2001).

Project Identification

Projects to be studied were identified based on the working definition of PPB (see Executive Summary) and the researcher's prior knowledge of PPB partnerships, resulting from direct involvement in the Northern Plains Sustainable Agriculture Society's Farm Breeder Club (FBC) and participation in the 2003 and 2005 Seeds and Breeds Summit meetings. Seed multiplication and distribution, although part of the working definition of PPB, was outside of the scope of this study. Two projects initially investigated did not fit the working definition of PPB through a lack of involvement of end-users/farmers in genetic improvement activities; these projects were not included in the study,

Primary Data Sources

Primary data were gathered from key actors in the Organic Seed Partnership (OSP), Restore Our Seed (ROS), FBC, Organic Seed Alliance (OSA), Michael Fields Agricultural Institute (MFAI)/USDA-ARS Corn Insects and Crop Genetics Research (ARS)/Practical Farmers of Iowa (PFI), Northern Grain Growers (NGG) and participating LGUs, including North Dakota State University, Washington State University, University of Maine, Cornell University, University of Wisconsin-Madison, Oregon State University, and University of Vermont. (See Table 2 for year of establishment information for each of the PPB projects.)

Secondary Data Sources

Secondary data were gleaned from publications including journal articles, newspapers, magazines, and websites. Project files, including yearly progress reports, project evaluations, field day proceedings, reports to funders, and publications, were utilized to triangulate with the interview data.

Table 2. PPB organizations/projects participating in this study

PPB Organizations/Projects	Year Established
Farm Breeder Club (FBC)	1999; project of Northern Plains Sustainable Agriculture Society
MFAI/ARS/PFI PPB Corn Project	1999; partnered with USDA-ARS 2003
WSU Participatory Wheat Project (PWB)	2000; Organic Wheat Breeding Project funded in 2006
Organic Seed Project (OSP)	2001-2004 as the Public Seed Initiative; led to OSP 2005-2008
Restoring Our Seed (ROS)	2002
Organic Seed Alliance (OSA)	2003; formerly Abundant Life Seed Foundation, established 1975
Northern Grain Growers (NGG)	2004

Sampling

A snowball sampling process was utilized. The inquiry process was initiated with interviews of nonprofit facilitators of PPB projects. At the end of the interview the facilitators were asked to recommend partnering farmers, scientists and extension specialists for further interviews about the project. Interviews were conducted with this subset of PPB partners providing a diversity of perspectives. Respondents representing the seven PPB partnerships participating in this study included 12 organic farmers, 6 nonprofit facilitators, and 12 scientists/plant breeders.

Interview Process

Interview questions were constructed utilizing the AI approach organized under the CC framework, resulting in seven categories of questions. The interviews were conducted by phone; each of the interviews were recorded and transcribed.

Analysis

Interview transcripts and the secondary sources were qualitatively analyzed for changes in the seven community capitals. The study utilized template analysis based on the seven *Community Capitals*, incorporating *Latour's Circulatory System of Science* and the *Learning Approach* framework under social capital and the *Resilience* framework under natural capital. A second tier of coding subcategories was utilized to further organize the data to provide for more efficient analysis.

The analysis involved the construction of three matrices. First, the data was grouped under each category, with the data summarized for each community capital as a whole. Second, the data was sorted into three interview classes: farmers, scientists, and facilitators and to look for similarities and differences among respondent classes. Third, the data was broken down and sorted into the individual PPB partnerships to look for similarities and differences between the projects. A comparative matrix was developed with a side-by-side analysis of the variables around which PPB projects can be organized. Finally, a graphic analysis was conducted of the social learning linkages between PPB partners, other PPB projects, national and international organizations and agencies and the organic seed industry.

ANALYSIS-- MOBILIZING & BUILDING COMMUNITY CAPITALS

Social Capital

Mobilizing Bonding and Bridging Social Capital

Organic farming systems were developed by farmers and the nonprofit educational networks they formed for support; they grew outside of and with little support from the LGU system. Consequently, organic farmers had few beneficial relationships with research and extension specialists, and plant breeders. Three organic farmers and two nonprofit participants reported that some land grant universities exerted pressure from administrative levels, making it politically untenable for land grant researchers to work with organic farmers. The lack of responsiveness fostered frustration and distrust of LGUs within organic farmer networks.

One plant breeder felt that the land grants were perceived by some within the organic community as "a big nasty research institution supported by multinational companies." A farmer participant shared his perspective, stating, "Fifteen years ago it didn't seem like we had much help at all coming from extension or the land grant colleges. It was a point of frustration for most of us out here in the organic world and we were throwing up our hands and saying, 'That's too bad.'" A LGU plant breeder acknowledged that when organic farming stakeholders approached their land grant institution with their needs and concerns over plant breeding for organic systems, the response was less than cooperative. "I think we missed an opportunity to establish some good alliances with organic growers and people who were interested in participatory plant breeding."

Public plant breeders, organic farmers and the nonprofit organizations that serve them began to bridge those negative perceptions and gaps in service by building capacity and support through participatory variety trials. Many LGUs lacked certified organic land, leading to on-farm organic variety trials and organic seed company trials of land grant varieties. Some land grant participants acknowledged they had never visited an organic farm prior to the trials; the experience exposed them to organic production systems and a new set of stakeholders, helping to dispel preconceptions and elucidate the research needs of organic farmers. New relationships were formed in the service of organic seed development and organic farming systems. One plant breeder stated, "Some of my colleagues who were not supportive of working in organic systems are working in organic systems now."

Mobilizing Social Capital Through Feedback Loops: The Circulation of Science

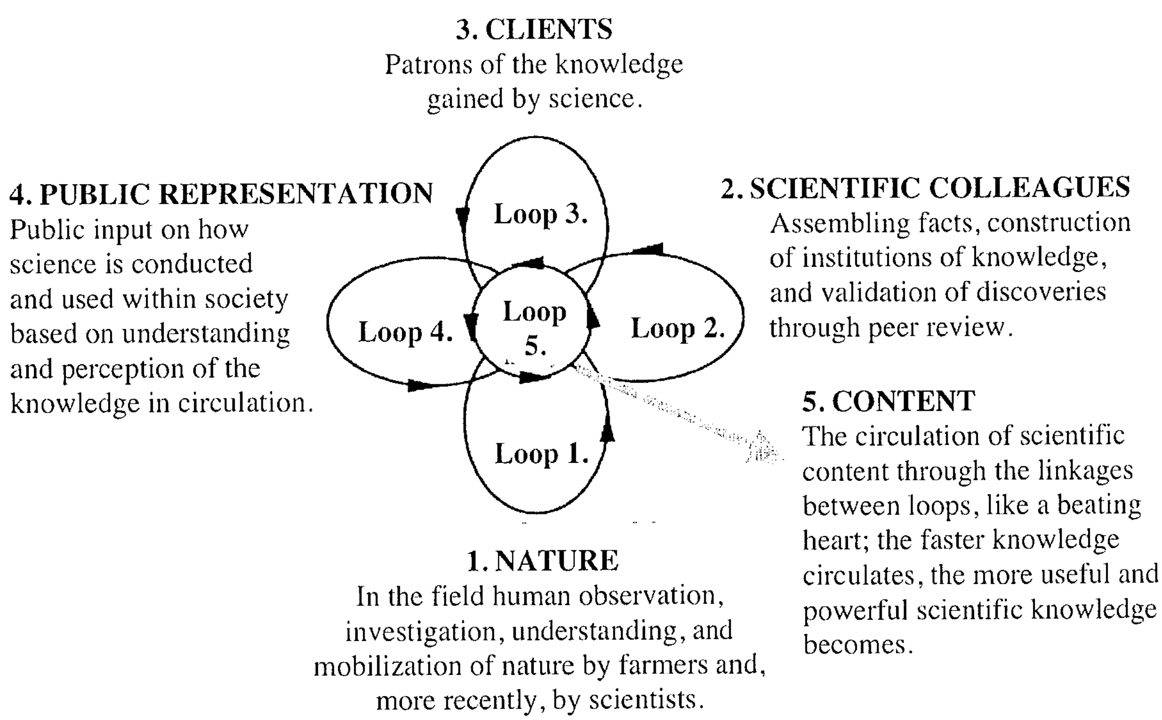
Bruno Latour's Circulatory System of Science (Figure 2) offers a framework for understanding the socialization of scientific knowledge and the mobilization of social capital. Latour views scientific knowledge, not as "pure" and "isolated" from social context, but as a powerful and persuasive social activity in which scientists are social actors. He purports that scientific knowledge is utilized to "enroll" actors in collaborative networks by offering the possibility of rewards and benefits through their association.

PPB partnerships are what Latour referred to as a hybrid social/scientific network. PPB not only provides access to specific skills, knowledge and germplasm, it provides farmers with plant breeding professionals as partners and vice versa. What the farmers bring, according to one plant breeder, is an intimate knowledge of their farms' environments and their farming systems (Loop 1), which is particularly important in organic agriculture. "They also have the unique perspective of literally seeing what's going on out there on a daily basis. And they've experienced generations of crops in the context of their farming systems." Farmers' intimate contact with nature is mobilized through partnerships between farmers and scientists, significantly increasing the linkages and circulation of knowledge between Loops 1 and 2. PPB recognizes the scientific value of both the farmers' and scientists' ways of knowing. They become both colleagues and clients to one another, each benefitting from the synergies between their pools of knowledge and experience. One farmer stated, "There is an actual connectedness and excitement on the part of the breeder, working with a human being that is actually going to plant their seed. Likewise, as a grower I'm working with someone who has invested their life and energy into an academic pursuit of seed breeding and understanding genetics… it's a shared experience and a respect from both sides of the seed equation. And it's personalized."

"For Latour, scientific knowledge is more powerful and more persuasive as it flows through society" (Warner, 2006, pg. 30). The organic industry recognized the power of leveraging social change through science early on. The Rodale Institute (RI), established in

1947 by organic pioneer, J.I. Rodale (RI, 2009), and the Michael Fields Agricultural Institute (MFAI, 2009), established in 1984, endeavored to revitalize agriculture by conducting research on organic farming systems and providing education, technical assistance and advocacy. The Land Institute (TLI) was established 30 years ago with the purpose of developing a, "Natural Systems Agriculture" (TLI, 2009). In 1990 the Organic Farming Research Foundation (OFRF) was established to link organic farmers with scientists in participatory research partnerships, sponsoring peer-reviewed research on organic farming systems, disseminating the results to organic farmers, and educating consumers and policy-makers (OFRF, 2009). In 2002 the Organic Center (TOC) was established "to generate credible, peer reviewed scientific information and communicate the verifiable benefits of organic farming and products to society" (TOC, 2009). These research institutions help to ensure that scientific knowledge flows quickly and efficiently through all of the Latourian loops.

Figure 2. Latour's circulatory system of science (Modified from Warner, 2006).



The Tri-Societies [American Society of Agronomy, Crop Science Society of America, Soil Science Society of America (ASA-CSSA-SSSA)] hosted an Organic Symposium at the November 2003 Tri-Societies Annual Meeting, the first Organic Symposium since 1981. A round-table discussion was held in conjunction with the symposium. A second round table was held in 2004 resulting in the formation of the Committee on Organic and Sustainable Agriculture (COSA). The FBC partnered with the Council for Agriculture Science and Technology, the Institute for Conservation Leadership, and the Tri-Societies in 2004 through a Kellogg Foundation initiative, *Cultivating Leadership for a Changing Agriculture*, to sponsor a planning retreat on PPB. The retreat led to a panel discussion at the Crop Science Society Annual Meeting in November 2005 entitled, "Developing Farmer-Breeder Teams," held in conjunction with the Tri-Societies Annual Meeting (Zwinger & Podoll, 2006). In addition COSA sponsored an Organic Symposium as part of the 2005 Annual Meeting, entitled, "Organic Seed Production and Breeding for Organic Production Systems." Participants in the FBC, OSP, OSA, and WSU-PWB projects made presentations along with OFRF's Organic Research Specialist, Jane Sooby (Sooby, 2005). In 2007 the American Society of Horticultural Sciences Annual Meeting hosted a session entitled: Breeding Horticultural Crops for Sustainable and Organic Production. Presentations included the OSP, the OSP broccoli project, and WSU-PWB (ASHS, 2009). These relationships strengthened the circulation of knowledge through Loops 1 and 2.

OSA was formed in 2003 to support the ethical development and stewardship of agricultural seed. OSA has become a networking hub of PPB plant breeding information and activity, forming collaborative and collegial relationships between farmers, plant breeding professionals, and seed companies, circulating knowledge through Loops 1, 2, and 3. OSA hosts a biennial Organic Seed Growers Conference in Oregon. In 2009, recognizing the need to network organic seed growers with the larger organic food and farming sector, Organic Seed Alliance joined Oregon Tilth, the Food Trade Sustainability Leadership Association and Organically Grown Company in hosting the first *Organicology Conference*. PPB partnerships and seed issues played a prominent role in the educational program, facilitating the circulation of knowledge from Loops 1, 2, 3 and 4.

PPB for organic farming systems has also capitalized on existing marketing relationships. "The values of the organic community and many of the seed companies serving the organic community grew out of a grassroots collaborative stakeholder process," stated one participant. "[Stakeholders] recognize that as part of the culture and value in this market. To be successful they need to engage in that [collaborative] process... becoming this collaborative feedback loop amongst all the players."

There are many potential traits of interest to organic markets. Processors and retailers are stakeholders and clients represented in Loop 3; they are looking for crop varieties with specific traits, such as enhanced nutritional qualities, and taste. Point-of-purchase taste-testing and feedback from retailers and farmers using direct marketing provide a valuable feedback loop to the plant breeding efforts. "Conventional [agriculture] is more in the commodity mindset," one participant stated. "Organic producers are more mindful of what the market wants; they are closer and more responsive to the consumer." This marketplace linkage provides feedback from Loop 4, which circulates back throughout the PPB network through Loops 1, 2 and 3. One plant breeder stated, "If you don't have the feedback links and that connection then there's no point in doing any of this. And I think we've done a good job in that but we can always do better." Organic agriculture has grown to the point where there is now an organic commodity market. Incorporating organic commodity players into those feedback loops is worthy of further examination.

One important aspect of Loops 3 and 4 is that of public policy. Policy-makers are clients of scientific knowledge and simultaneously represent the public interests in Loop 4. The public response to the USDA's proposed rules for the enactment of the Organic Food Production Act (1990), published in the December 16, 1997 issue of the Federal Register, was the largest public response to a proposed rule in USDA history, drawing over 275,000 comments (Golan, 2000). This clearly demonstrated the functioning of Loop 4 and the public's engagement in policy-making based on their knowledge of the science behind organic agriculture and their individual perceptions of how that science should be mobilized within society. It demonstrates the strong social and political capital that can be mobilized and built upon by the organic sector.

Partnership Models

PPB is a partnership of market, state and civil society. Land grant universities represent the public sector; NGOs represent civil society; and farmers, seed companies, processors, and end-users comprise the private or market sector. Each partner brings unique skills and resources to the partnership. Farmers have the opportunity to observe how the crop responds to their farms' environments and help identify the agronomic traits needed to perform under those conditions. Seed companies, millers and bakers, processors, wholesalers, retailers and farmers provide valuable input on desirable and marketable quality traits. "The classical plant breeder knows how to isolate those traits. They test the new crosses on-farm, relying on the farmers' expertise to select the best material, as the farmers get to intimately know the material over the course of the season" (OSA, 2008).

PPB partnerships are a social construction and can be better understood by considering a number of parameters around which they can be organized. Who initiated the project and took the lead role? What breeding methods are employed? What is the level of interaction between the partners? At what stage in the breeding process does the interaction take place? Table 3 (modified from Morris and Bellon's matrix in Table 1) provides a depiction of how the partnerships in this study functioned across those parameters. Most of the partnerships were practicing what Morris and Bellon (2004) call "complete" PPB, with both scientists and farmers interacting throughout the breeding stages. The FBC and OSA sweet corn and zucchini projects fall into the category of "efficient" PPB. ROS Dancing Greens represents "traditional farmer breeding."

Attributes

Study participants identified a mutually respectful, trusting relationship as a crucial attribute to a project's success. Plant breeding requires sensitivity to both the grower's needs and consumer's needs. One farmer stated, "You have to be willing to listen to what each other is saying. A breeder knows things a farmer doesn't know, while a farmer knows their farm and their markets better than the breeder." One plant breeder stated, "I think [the farmer] knows what he wants. We [plant breeders] don't know what he wants. There has to be the connection with the growers." Other crucial attributes listed included communication, cooperation, good facilitation, inclusive planning and evaluation,

Table 3. Participation models utilized by PPB Partnerships studied

PPB Projects	ROSdg[1]		FBC[2]		OSAwc[3]		NGG[4]		MFAI/ ARS/PFI[5]		WSUwh[6]		OSPpmc[7]		OSPpwp[8]		ROSdrc[9]		OSAscp[10]		OSAzp[11]		OSPbp[12]	
Initiation & Lead	F		F		F+S		F		S, F, F+S		F, F+S		F+S		F+S		F+S		F		F		S	
Type of Breeding*	Population		Population		Population		Both		Both		Both		Pedigree		Pedigree		Both		Population		Population		Population	
Interaction**	Cn		Clb		Clg		Clg		Clg		Clg		Clg		Clg		Clg		Clg		Clg		Clb	
PB Stages	**F**	**S**	**F**	**S**	**F**	**S**	**F**	**S**	**F[14]**	**S[14]**	**F**	**S**	**F**	**S**	**F**	**S**	**F**	**S**	**F**	**S**	**F**	**S**	**F**	**S**
Germplasm eval.	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*
Prioritize traits	*		*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
ID parent material	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*		*
Make crosses	*		NA[13]	NA[13]	*		FC[15]	*	*	*	FC[15]	*	FC[15]	*	FC[15]	*	FC[15]	*		*		*		*
Selection work	*	SA[17]	NS[16]		*	*	*	*	*	*	*	*	*	*	*	*	*	SA[17]	*	*	*	*	*	*
Final evaluation	*		*		*	*	*	*	*	*	*	*	*	*	*	*	*	SA[17]	*	*	*	*	*	*

F-Farmer; **S**-Scientist   Traditional Farmer Breeding   Efficient PPB   Complete PPB

Acronyms

[1]ROS	Restoring Our Seed Dancing Greens	[2]FBC	Farmer Breeder Club
[3]OSAwc	Organic Seed Alliance winter carrot	[4]NGG	Northern Grain Growers
[5]MFAI/ARS/PFI	Michael Fields Agricultural Institute/[USDA] Agricultural Research Service/Practical Farmers of Iowa	[6]WSUwh	Washington State University wheat breeding project
[7]OSPpmc	Organic Seed Project powdery mildew resistant cucumber	[8]OSPpwp	Organic Seed Project peacework pepper
[9]ROSdrc	Restoring Our Seed disease resistant cucumber	[10]OSAscp	Organic Seed Alliance sweet corn project
[11]OSAzp	Organic Seed Alliance zucchini project	[12]OSPbp	Organic Seed Project broccoli project
NA[13]	Not applicable-- no crosses have been made		
F[14]S[14]	Interactions vary by project but the partnership includes projects with collegial interactions at all stages of breeding		
FC[15]	Farmers can choose to make their own crosses; if they choose not		
NS[16]	Primarily natural selection pressure	SA[17]	Scientist available for consultation

*Type of breeding- Population, Pedigree, or Both [Note: Some partnerships utilize either pedigree or population breeding based on the goals of individual breeding projects; denoted as 'Both'.]

****Interaction**

Cn	Consultative-- information sharing
Clb	Collaborative-- task sharing
Clg	Collegial-- sharing responsibility, decision-making and accountability

understanding of partner resources and capabilities, clear roles and responsibilities, and transparent and shared decision-making.

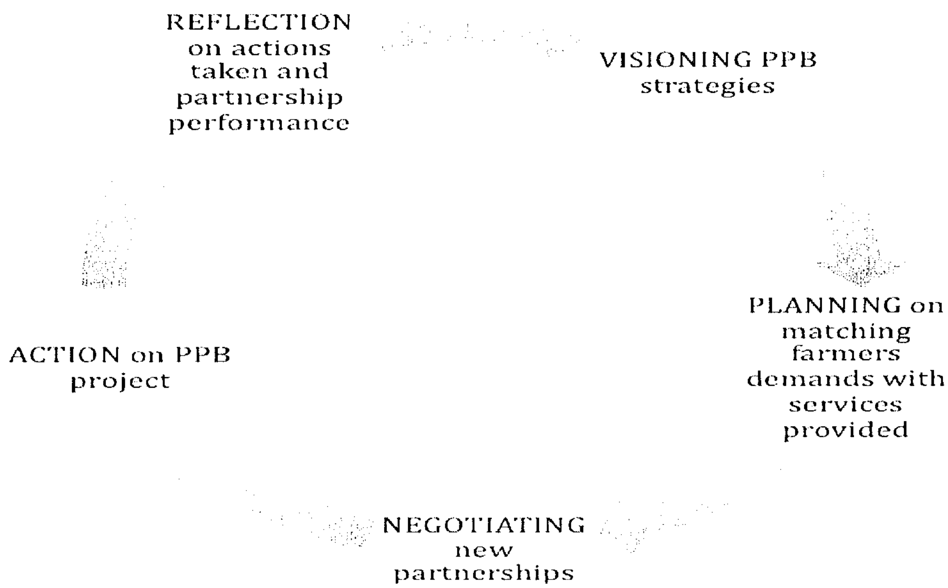
Many of the participants acknowledged that PPB is not for everyone. "I think it takes a special person to do a project like this and carry it through. It takes a lot of patience and persistence," one plant breeder observed. "There is a curiosity, a certain amount of education, and 'stick-with-it-ness' in individuals that will carry through." Another plant breeder stated, "The farmers I was working with are pretty sophisticated— very inquisitive, always trying things on their farm— innovative." Respondents from all categories— farmers, NGOs, and scientists-- stated that people interested in PPB tend to be advocates for publicly held seed and are aware of the politics of seed.

The Learning Process

The attributes identified by participants as crucial to success are strongly linked to the learning process (Figure 3). PPB entails mobilizing social capital through shared decision-making to establish and build the cultural capital that provides for a shared vision. This necessitates that all potential partners have a voice in the planning and development of the project, including determining goals, objectives, approach and methods; negotiating partner roles and responsibilities; establishing communication; and planning reflection and evaluation procedures (Lightfoot, 2001). This is especially critical in terms of the farmers' voice and that of the nonprofit organizations that represent them. It requires significant time and effort. The process is often truncated by time constraints of those organizing the planning process and the realities of deadlines for grant applications and reports.

Thoughtful and appropriate partnering requires skillful planning and facilitation. Last-minute PPB partnerships lacked planning, did not incorporate the phases of the learning process, and resulted in other partners taking on added responsibilities to meet the objectives of the project, often beyond the resources they had to commit. Last minute partnerships left some feeling as though they were token participants rather than full partners, asked to participate because their involvement would make the project more attractive to potential funders. "Just to be told, 'You can come in and we will give you $XX-thousand per year to do this, this and this.' It doesn't serve our needs," stated one nonprofit study participant.

Figure 3. Phases in the learning process (Adapted from Lightfoot, 2001.)



Planning, decision-making, reflection and evaluation must continue to be a joint process, cycling through the learning process again and again to gain everyone's input, receive feedback, and make course adjustments to ensure the projects and programs effectively fulfill the needs and goals of the partnership on an ongoing basis. "The project failed to involve the larger community in assessing what the real constraints were and coming up with possible solutions," stated one participant, adding, "The partners had only minimal input into the assessment and evaluation work."

Bypassing the reflection and performance evaluation undermined ongoing relationships and long-term goals. One nonprofit participant, who was invited to participate in a follow-up project, stated, "They were really pushing us to participate.... and were gravely disappointed [that we declined] but to their credit they understood exactly what I was saying. You have to be part of the planning process to ensure it serves your needs and matches your capacity to deliver– or in the long run it hurts the project, our organization and our growers."

Organizational Structure for Learning

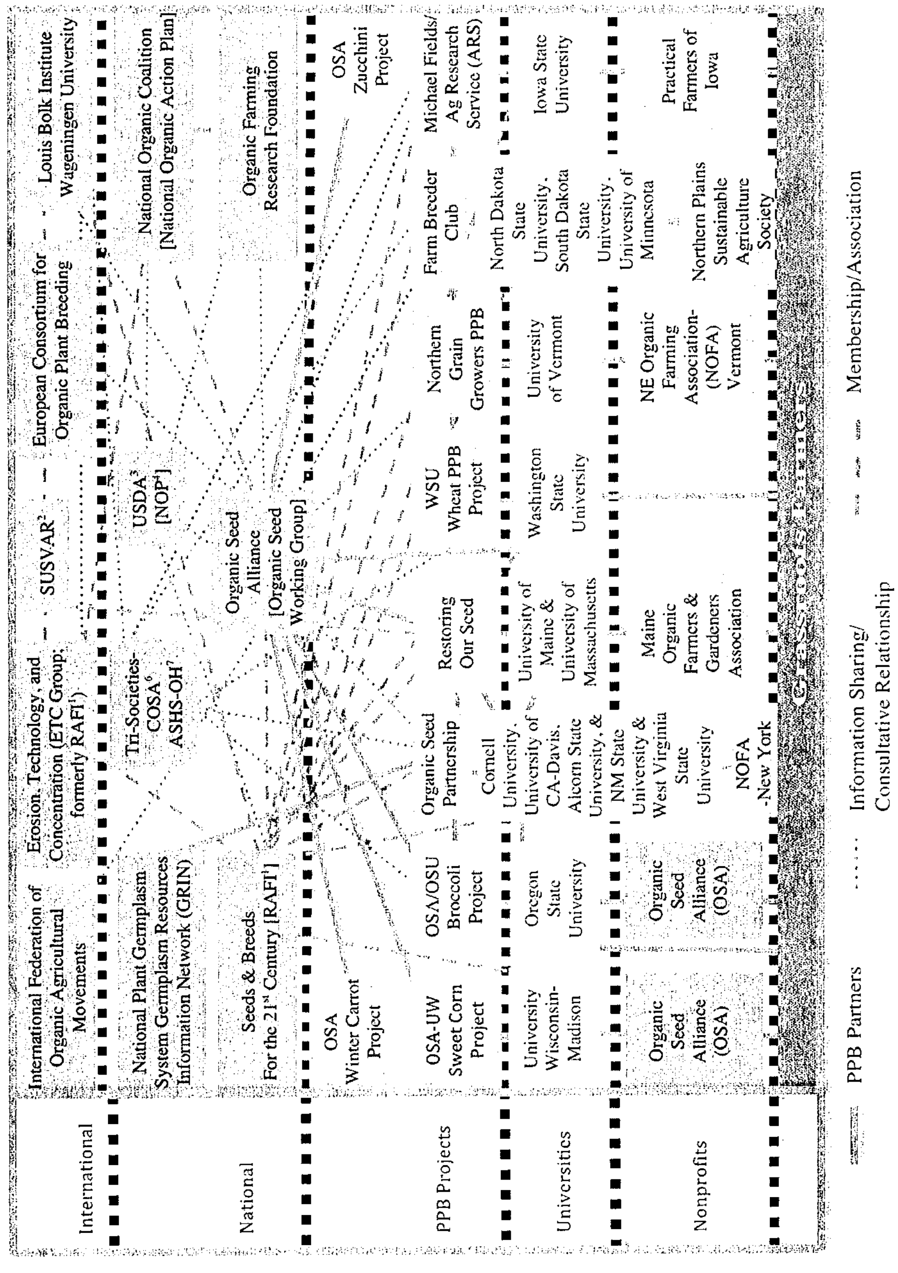
PPB is a participatory action learning approach to development (Röling & Wagemakers, 1998). The learning structure includes linkages at local, state, regional and national levels (Lightfoot, 2001). The linkages between the PPB projects revealed in this study, including university and nonprofit partners, and national level organizations are depicted in Figure 4. Linkages with organic seed company partners are depicted in Figure 5.

One PPB partnership, the Farm Breeder Club, emphasized the social learning process. At the outset of the project a working group was formed to explore PPB partnership models between public plant breeders, land grant universities, farmers, and end-users (millers, bakers, processors, and distributors). The FBC working group was comprised of land grant plant breeders, organic seed producers, organic farmers, a social scientist and an agricultural economist/extension specialist. Included in the model they sought to develop were self-funding strategies for PPB projects and strategies for dealing with university relations, material transfer agreements and intellectual property.
The working group fostered outreach to other nonprofit organizations, PPB partnerships and seed saving systems, networking with them and fostering an organizational structure for learning. A planning and networking meeting was held in conjunction with the 2005 Seeds and Breeds Summit. PPB partnerships represented were ROS, OSP, MFAI/ARS/PFI, OSA, and FBC. The purpose of the meeting was to exchange information on the PPB learning models being developed and to learn from the experiences gained in their development (Zwinger & Podoll, 2006). A staffing change at the nonprofit level ended the FBC working group effort. Networking between PPB partnerships has continued and progressed informally at the 2008 Seeds & Breeds Summit and at biannual OSA Seed Conferences.

Human Capital

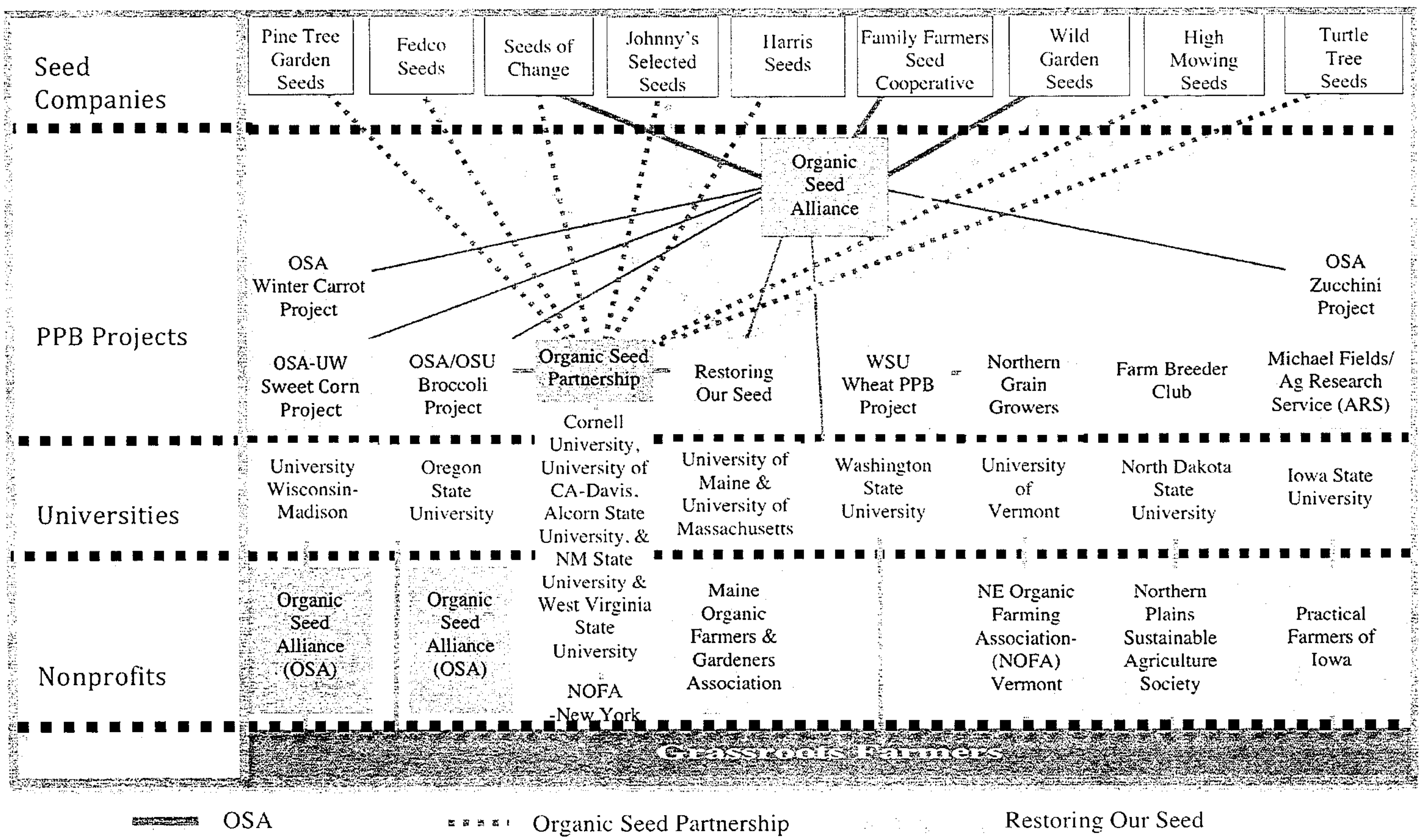
As state and federal investment in public plant breeding has declined, as seed breeding has become increasingly isolated to private and corporate plant breeding departments, and as the seed industry has become increasingly consolidated, human capacity has also eroded. Many public plant breeding programs are seriously underfunded. From 1994 to 2001 plant breeders employed by state agriculture experiment stations declined by 21% (Taxler et al., 2005). "As much as we don't think of the United States as having similarities to developing countries in terms of its seed infrastructure and even its

Figure 4. Linkages supporting the PPB social learning process



[1]RAFI—Rural Advancement Foundation International
[2]SUSVAR—**SUS**tainable low-input cereal production: required **VAR**ietal characteristics and crop diversity
[3]USDA—United States Department of Agriculture [4]NOP—National Organic Program
[6]Tri-Societies-COSA—American Society of Agronomy, Crop Science Society of America, Soil Science Society of America—
Committee on Organic and Sustainable Agriculture
[7]ASHS-OH—American Society of Horticultural Science- Organic Horticulture Network

Figure 5. Linkages between PPB projects and organic seed companies



agricultural research infrastructure... we were very compromised," stated one plant breeder. "There had been a lot of budget cuts and loss of faculty, loss of companies in the area, loss of trialing capacity. In fact if we were honest about it we were pretty impoverished." In a presentation to the American Society for Horticultural Science, Molly Jahn, current Dean of the College of Agriculture and Life Sciences at the University of Wisconsin-Madison, stated that the public system is seriously eroded to the point where she believes it is not going to come back (Jahn, 2007). Other study participants reference the erosion of public plant breeding capacity as evidence of the critical need to develop participatory models for plant breeding, empowering farmers to help fill the gaps.

Mobilizing Human Capital

Scientists

One farmer said of public plant breeders, "They believe in the public plant breeding system; most of them have dedicated their life's work to that system." He added, "It has been [their] life. [They have] all of this information... access to all of this [germplasm] material and relationships with breeders all over the world. That sort of thing is invaluable to a collaborative effort." Another farmer stated, "They had training days up at the greenhouses that actually showed us the pollination-- the hand pollination of almost any type of crop you can imagine. I mean you can read it in the book and you can play around with it, but when you work with someone that's been doing it his whole life and they are showing you techniques... It was really informative." He added, "I don't think I'd be doing half of what I'm doing now. I'd probably just be doing natural selection on my farm." Yet another farmer stated, "If the grower had the option to trial out seeds and have someone respected in their field come in and go through it with them – what could be better than that? I won't look at plants the same way again."

Agroecological systems are complex, interactive and co-evolutionary. One PPB partnership is interested in partnering with plant pathologists and soil scientists in looking at the soil microbiology and how that interplays with the choice of varieties and crop rotation. This is just one example of the many interdisciplinary projects PPB partnerships could undertake.

Farmers

One participatory plant breeder stated, "Cecarelli does show, and he's published many times over, that the farmer in general has a better eye than the breeder. A lot of breeders might recoil from that statement but with me, it's just fine." Nonprofit partners and plant breeders underscore the importance of mobilizing farmer knowledge. "It has been demonstrated through millennia that farmers can be excellent breeders when given the resources and knowledge" (Jahn, 2008). A farmer participant stated, "The breeders… said that growers are better situated to pick and select strains and qualities of interest to them."

Diversity

PPB provides plant breeders with the ability to essentially "farm out" more of their efforts among cooperators, mobilizing a diversity of perspectives. Plant breeders acknowledge that simply having a cadre of farmers willing to take material and grow it out in their different farming environments provides very valuable information and services to them. "Doing so allows partnerships to work with more plant populations of diverse germplasm instead of relying on one person [the plant breeder] to make all of those decisions under pressure of limited funding and time," one plant breeder observed. The exposure to a plethora of varieties and discussing the traits they exhibit from a plant breeder's, farmer's, and also the processor's perspective is a vital exchange in the PPB process. This exchange can better target limited plant breeding dollars, mobilize partner's knowledge and resources, and may enhance utilization of the varieties produced (Witcombe et al., 2003). One plant breeder stated, "I think it's the marriage that was dissolved 50 years ago. And now it's back."

Farmers engaged in the process of shaping the look of the plants and their agronomic and market traits. Starting those conversations in the early stages of the plant breeding process enabled farmers to take part in those decisions. One plant breeder stated the majority of farmers used their enhanced breeding knowledge to make better selections and do a better job of producing seed. "I've learned to stop and take time and actually look at the plants; walk your field and really observe," stated one farmer. "I have always been an observer but instead of just looking at your whole field, you are looking at individual plants-- How long is the head? How hard is it to thrash? --all the little things that add up to make a good variety... that's what makes farming so much fun."

Priorities

Farmers may feel they do not have the time, resources or inclination to take this work on. "That is understood," said one plant breeder. "I think farmers are challenged to find the time to do this sort of thing but I think it can be done with partnerships." Many participants pointed to public-private partnerships to provide the mutual support and efficiencies needed to do this work. A 2006 survey of wheat growers in Washington State found that over half of the respondents were "very/somewhat interested" in working directly with WSU scientists in participatory wheat breeding programs (Dawson & Goldberger, 2007). In response one plant breeder stated, "If this makes sense for a grower then I would be surprised if they don't have the time." One farmer stated, "I think we [farmers] do have the time; it's a matter of prioritization."

"There are some farmers who have a proclivity to work with seed and others who don't. Some just receive the seed and others participate as appropriate to them," one participant observed, "If you are a reluctant player it's not going to work." The Restoring Our Seed project refers to those farmers who have a proclivity to work with seed as "lead farmers." These farmers inspired other farmers and those relationships evolved into farmer-led breeding projects.

Building Human Capital

"To have a local seed economy you have to have farmers who have the expertise to potentially do on-farm breeding; farmers need to have the skills and equipment to produce seed, make good selections, clean the seed, and share the seed amongst themselves," stated one plant breeder. "It is actually a goal to empower farmers to do that."

According to project reports, PPB projects inspired farmers to become seed savers at some level. Farmers who were already doing some seed saving prior to their involvement, increased their seed saving skills and activities. One farmer reported increasing her seed activities to meet 40% of her seed needs. Others contacted small organic seed companies to explore growing seed on a contact basis.

The Organic Seed Alliance estimates less than 10-15% of the farmers they work with progress to more complex plant breeding activities. There are those farmers who were interested in simply hosting variety trials, learning about new and exotic germplasm. Others learned how natural selection pressures could adapt a genetically diverse population to the environmental conditions of their farms. Others pursued a more active role in the plant breeding process, performing progeny selection for agronomic and quality traits. Still others worked with plant breeders to learn how to make their own crosses, followed by progeny selections.

Natural Capital

"Natural capital is the base on which all other capital depends. It is a landscape, climate, air, water, soil, and biodiversity of both plants and animals" (Flora & Flora, 2008, pg. 17-18). Seed is a primary resource in farming systems. As varieties are dropped by the seed trade, farmers must find replacement varieties that are suited to their climate, farm, and markets.

Existing Natural Capital Mobilized

Organic farmers involved in PPB projects equate the importance of managing their germplasm to that of managing their farm's soil quality. Germplasm access is critical to PPB efforts. Public plant breeders have access to germplasm and a collection of varieties that they been working on and selecting over their years of experience as plant breeders. Most LGUs have parental lines and populations in their programs that they have developed for years that can be used to cross with varieties the participatory partners identify as having traits of interest but require improvement. Some LGUs engaging in PPB have provided breeding populations to PPB partners. Public germplasm can also be accessed through numerous local, state, national and international seed saving networks, such as Save Our Seed, Southern Seed Legacy Project, Native Seed SEARCH and the Seed Saver's Exchange. The Germplasm Resource Information Network (GRIN) / National Plant Germplasm System has more than 500,000 accessions (distinct varieties of plants) in the GRIN database. These accessions represent more than 10,000 species of plants (USDA-ARS, 2009).

Germplasm evaluation is the first step in mobilizing the plant breeding process to build on existing natural capital. On-farm organic variety trials provided organic farmers the opportunity to observe the performance of existing commercial varieties, crop varieties in USDA holdings, and plant breeders' experimental varieties. The trials included the standard varieties currently being utilized on organic farms, providing side-by-side performance, yield and quality data along with observational data on traits useful in organic farming systems.

Plant breeding is always a compromise and the partnership must establish what traits to prioritize in the breeding process. Cultural practices impact breeding priorities. For example, as a conventional broccoli breeder, breeding for flea beetle resistance would be high on the list of priorities. One farmer-breeder team for a participatory broccoli project found that the organic farmer's cultural practice of incorporating white oak leaf litter into broccoli beds minimized flea beetle pressure. Another farmer participant observed that his cultural practice of allowing brassicas to overwinter for spring production significantly reduced flea beetle damage. These practices allow other traits to become breeding priorities, underscoring the need to integrate plant breeding activities into the organic farming system in a co-evolutionary process.

Once the partnerships evaluated the germplasm available and determined their breeding priorities, they selected the parent material they would mobilize to meet their needs. Most of the participatory breeding projects used an approach called population or evolutionary plant breeding (see Table 3, pg. 16). To meet organic farmers' priorities for stability and resilience in diverse and variable environments, the partnerships strived to supply germplasm with the genetic diversity and variation needed to provide for adaptability and the development of broad resistance to disease and pest pressure-- known as horizontal resistance. Partnerships created diverse gene pools, using the parent material they had selected, breeding several varieties together. Some partnerships accessed existing land races of a particular crop. The genetic diversity within these populations or land races could be mobilized for selection and adaptation to agroecological and socio-economic needs.

All of the partnerships worked to develop or improve open-pollinated varieties, although a few of the partnerships also pursued some hybridization projects. Open pollinated (OP) varieties are viewed as a good fit for organic farming systems; they remain adaptive to where they are being grown and provide farmers the option to save their own seed. Saving hybrid seed may result in seeds that are sterile or, more commonly, fail to breed "true," meaning the seed produced lacks the desirable traits of the hybrid variety. The ability to save seed from OP varieties year to year provides the basis for selection and adaptation to the local environment, farming system, and markets. Both farmers and plant breeders made statements that OP varieties can be bred to do anything hybrid varieties can do; they just haven't received as much attention as hybrids.

Building Natural Capital

Diverse gene pools enabled farmers to adapt the material to their farm's environment, farming system and markets, providing for resilient agroecological and socio-economic relationships. Every farmer could interact with the population differently, making selections for desirable agronomic or market traits. The environment and farming systems also exerted natural selection pressures. Genetic diversity present within the gene pools to accommodate changes in agroecological and socio-economic conditions provides stability, resilience and sustainability. Table 4 lists the varieties and populations in development or released through PPB partnerships [See Appendix B].

PPB partnerships resulted in the enhancement of the natural capital of organic farming systems in six ways:

1. On-farm organic variety trials and the germplasm evaluation process led to the identification and adoption of existing and newly developed varieties that performed well, and exhibited traits of interest to organic farming and marketing systems

2. Farmers and plant breeders identified desirable crosses, creating pedigreed lines selected within organic farming systems with desirable agronomic, quality and nutritional traits.

3. Genetically diverse germplasm populations with sufficient genetic diversity to provide for adaptability were accessed or developed by the PPB partnerships; seed was increased and distributed to participating farms.

4. Selection pressure was applied to the germplasm populations, including environmental selection pressure (ie. pathogens, pests, weed competition and climate conditions), agronomic selection pressure (ie. harrowing, late or early season planting, crop

rotations), and quality selection pressure (ie. size, shape, color, taste, nutrition), which resulted in locally adapted varieties better suited to variable environments, organic farming systems, and organic markets.

5. Seed production allowed agronomic crops that are normally harvested prior to their flowering stage to go through their flowering cycles. This attracted a diversity of insects, including pollinators, further enhancing agrobiodiversity.

6. Increasing the agrobiodiversity employed on organic farms provided for in situ conservation of germplasm.

7. Increasing the agrobiodiversity employed on organic farms enhanced the resilience and stability of the agroecological and socio-economic system, supporting the farmers' ability to steward the resources under his care.

Cultural Capital

Mobilizing Cultural Capital

The industrialization of agriculture over the last 50 years has resulted in a corresponding industrialized and exclusive seed culture. The distance between farmers and plant breeders has grown increasingly wider. PPB has met with resistance at some land grant universities due in part to the perception that it is something that is done in the third world, where farmers don't have access to modern varieties. The notion that farmers should take a role in plant breeding does not fit the prevailing paradigm at land grant institutions. One plant breeder stated that when organic producers approached their LGU with their ideas for a PPB model, the response was, "Farmers don't do [plant] breeding." Another plant breeder had a similar experience, "I think the idea was that we have a private industry that can take care of those needs," one plant breeder stated, "...and why would farmers want to do their own breeding or selection work?"

PPB has broadened and deepened participants' view of the cultural value and impact of seed and of inclusive involvement of stakeholders in the plant breeding process. A farmer participant stated, "I had an instinctive and intuitive understanding of that but working with different people from the University has matured my view considerably." Participants from LGUs were impacted as well. "I came to realize the cultural value of seed even more. [The project] made me realize that farmers aren't thinking enough about their seed. I think they're taking it for granted. I think that has been a great revelation for me." Another extension participant shared, "[The project] definitely opened my eyes to the value of developing and saving seed... it wasn't until the farmers really sort of opened my eyes up to it that I really realized the importance of it."

One plant breeder commented, "Farmers used to take their show corn... big jars of their grain, and sheaths of every crop you can imagine to show at the fair. It was a great way to have some fun and show off what you could do. Those sorts of pride opportunities don't exist in a nameless, faceless commodity system. I think the opportunity is there for a rebirthing of the culture around seed and seed systems that used to exist."

Regionally developed varieties, the plant breeder who developed them, and the farmers who worked to improve them are once again being celebrated. Varieties identified as Native American or historical regional varieties have taken on cultural significance. For example, in Vermont the Northern Grain Growers have identified and resurrected three wheat varieties bred in the late 1800s by a plant breeder named Cyrus Pringle. The Vermont group was following the lead of the NPSAS Farm Breeder Club in the Dakotas, which trialed, milled, baked, and taste-tested numerous pre-1950s wheat varieties released by public plant breeders in the Northern Great Plains region. These historical varieties and their cultural history have generated tremendous interest among farmers, millers, bakers, and consumers alike.

One farmer and two plant breeders referenced the tremendous number of "mom-and-pop" seed companies that existed up through the 1970s. These independent seed companies developed their own seed varieties and worked with their local crop improvement associations to release them. "The potential is there to develop varieties that bear a regionalized identity or name-brand, much like the French culture around food. A classic example is the Vidalia onion, which has been a commercial success both inside and outside of the region," one farmer stated. Another farmer added, "We are hoping to develop a feeling of community identity and pride." Another farmer concurred, stating, "It generates tremendous excitement because of that feeling of community and community ownership."

Building Cultural Capital

From Seed Takers to Seed Creators: A Farmer-centric Seed Culture

Intellectual property regimes, used to protect breeding material and commercially developed varieties, continue to erode farmers' rights, making farmer-bred, farmer-owned, community and regionally-based varieties an attractive and empowering option. Farmers are often characterized as being price-takers rather than price-setters. One farmer involved in PPB stated, "In many ways you can look at [seed] the same way; we are seed takers, not seed creators." Another farmer echoed that theme stating that he is essentially a consumer, "We buy the catalog; we buy the seed."

One plant breeder stated, "The seed industry is in the hands of a few large companies. They are pricing the seed at whatever the market will bear, reducing choices for growers." Another plant breeder added, "Part of our goal is making sure that the large corporations do not consolidate the seed industry to the point where farmers become totally subservient to a corporate seed industry." One farmer stated, "It seems to me that the [public plant] breeders that were involved with us [had] a like philosophical bent. They believe in the public [plant breeding] programs. They want to serve the organic industry. They want to serve all the stakeholders in agriculture."

Participating in recreating the informal seed sector and furthering the development of the formal organic seed sector through PPB provided farmers with a means of re-establishing what the Organic Seed Alliance refers to as 'a farmer-centric seed system'. The benefits of PPB and farmer-bred, farmer-owned varieties include a greater diversity of ideas and people working with seed and a more competitive and bio-diverse seed industry. "It gave me as a farmer a much more secure feeling about the seed I'm using and the power I have to make changes. It's just part of the self-reliance impulse," one farmer stated. "It just seemed to make sense intuitively that saving your own seed would be a way to have more information, security and sovereignty over your production."

Seed sovereignty is at the heart of efforts to develop a model for open-source biology (OSB). "OSB is actually the analog in the biological sciences (including plant breeding) of the 'free and open source software' movement (FOSS)... A variety of analysts have begun to explore the possibilities offered by OSB" (Kloppenburg, 2008, p. 2-3).

Political Capital

Farmers taking part in PPB projects learned first-hand about plant genetic diversity and seed systems, why they have begun to narrow, and how the politics of agriculture and the seed industry is affecting them. There is a perception among the participants that there is a growing divergence of viewpoints on the future of agriculture and a growing gap between farmers and those that represent them. In many cases those who claim to represent farmers are in fact representing industry; commodity groups were cited as a prime example. Within these groups farmer needs are subservient to industry interests. Farmer feedback can be "muddled and muffled" as it makes its way through the political layers. In addition, the interests of organic farmers and other specialty producers are not represented by the conventional seed industry, commodity groups, and agricultural trade associations. These are the traditional agricultural representatives given credence and hearing by decision-making bodies within LGUs, state and federal agencies and government.

Many public universities have established research foundations whose job it is to deal with intellectual property, material transfer agreements for germplasm sharing and the licensing of varieties. The policies regarding material transfer agreements (MTA) and licensing requirements pose potential barriers to PPB projects. Increasingly public plant breeders are required by their universities to obtain MTAs before sharing germplasm, restricting access and the ability to participate in open-source crop improvement. Some of the farmers taking part in PPB projects refused to work with germplasm that required a MTA, citing organic principles and the need to build, not restrict, agrobiodiversity. These same farmers were reportedly pleased to learn about the publicly accessible germplasm provided through the NPGS; two farmer participants reported having accessed germplasm through the NPGS.

Mobilizing and Building Political Capital

Despite the lack of political capital in conventional channels, organic farmers have formed well-linked networks to mobilize research, education and advocacy around plant breeding for organic farming systems (see Figure 4). The Rural Advancement Foundation International (RAFI) mobilized relationships and networks among scientists, nonprofit organizations, and farmers to convene three summit meetings on Seeds and Breeds for the 21st Century beginning in 2003. The meetings discussed sustainable breeding programs, the current state of plant breeding, the privatization of the LGU system, and setting a sustainable plant breeding research and education agenda (Sligh & Lauffer, 2004). The 2005 and 2008 Seeds and Breeds summit meetings addressed building programs, infrastructure, and tools for sustainable and organic plant and animal breeding, and the development of a plan of action directed at the nation's Farm Bill. All of the PPB partnerships have taken part in the summit meetings, facilitating the networking among projects; all but one have made PPB presentations to these Summit audiences.

The resulting summit conclusions and policy recommendations were circulated and mobilized among congressional allies and within existing sustainable and organic agriculture policy networks. Such networks include the Congressional Organic Caucus, Organic Farming Research Foundation, National Campaign for Sustainable Agriculture, Sustainable Agriculture Coalition and Sustainable Agriculture Working Groups. Proponents of organic seed systems successfully advocated for the inclusion of language reading, "Developing new and improved seed varieties that are particularly suited for organic agriculture" as one of eight legislatively defined goals listed in the 2009 *Organic Agriculture Research and Extension Initiative* (OREI) request for applications. OREI is a federally funded program of the Cooperative State Research, Education, and Extension Service (CSREES). OREI funds research and extension programs that "enhance the ability of producers and processors who have already adopted organic standards to grow and market high quality organic agricultural products" (USDA-CSREES, 2009). Classical plant and animal breeding was also added as a purpose of the major USDA competitive research grants program, the *Agriculture and Food Research Initiative* (OFRF, 2008a).

There is a need for ongoing dialogue with program administrators, the National Organic Standards Board and certifying agencies working with farmers to ensure a feedback loop on the development of organic seed systems back to policymakers. It is critical that policy-makers understand why organic seed systems are lagging behind and the need for due diligence in researching and developing varieties suited to organic systems.

In 2009 the National Organic Coalition released the National Organic Action Plan (NOAP), developed through an organic community visioning process to articulate the future of organic food and farming. NOAP reiterates the Seeds and Breeds research priority of public plant and animal breeding, specifying a market-based objective of, "Expand[ing] localized site specific organic seed production capacities with a focus on improved nutritional, taste and disease-resistance qualities with the goal of meeting 50% of localized organic seed needs by 2020" (Henderson, 2009).

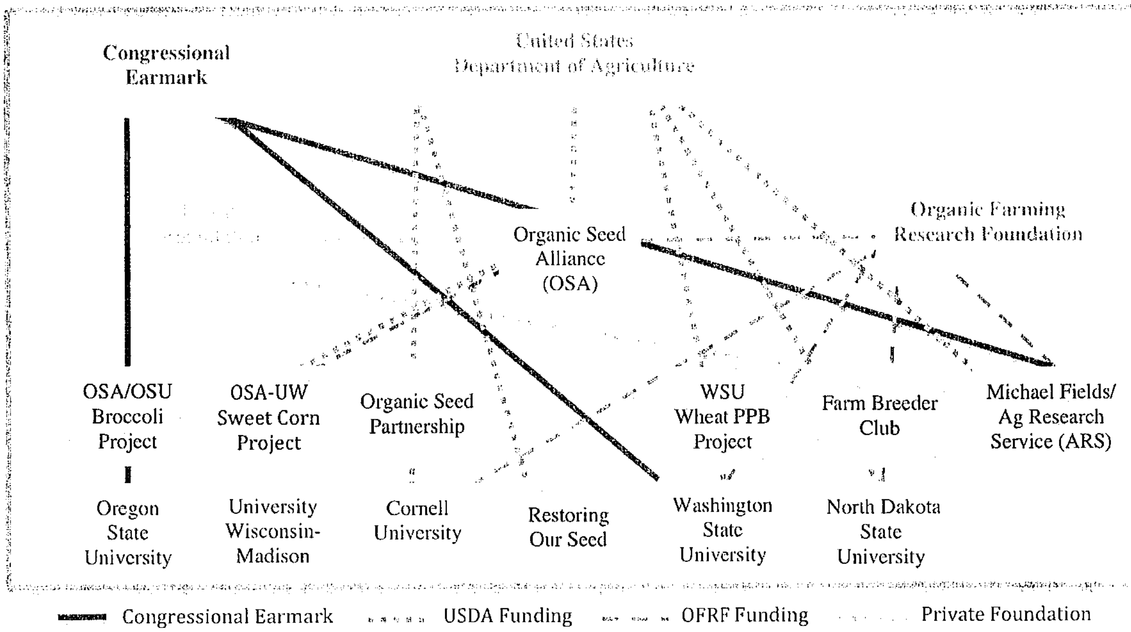
Financial Capital

Two plant breeders expressed that they are less hopeful for the future of public plant breeding systems than they were five year ago. There are fewer and fewer dollars supporting public plant breeding; resources continue to be funneled into genomics, and programs continue to find it difficult to cover expenses. "Costs go up but the funding doesn't. What you are able to do last year, you are not able to do this year," stated one plant breeder. Another plant breeder reported that $50,000 was cut from one of her breeding projects and given to genomics. Reinvestment in classical breeding programs and public seed systems is crucial to the ability of public plant breeders to partner with PPB projects.

Plant breeding programs require longer-term investments. All of the PPB projects were funded by short-term grants; the longest was a four-year federal grant for nearly $1 million. The OFRF has invested in numerous farmer-led, on-farm organic breeding projects, helping them leverage federal funds. Three PPB partnerships succeeded in generating "add-on" or "earmark" funding through their Congressional delegations (see Figure 6). One such earmark morphed into permanent ARS funding. Some projects are working to develop self-funding mechanisms through seed sales to generate research funds for ongoing breeding work. Others have developed relationships with private foundations and individual donors. One nonprofit organization was bequeathed a sizable endowment by an advocate for biodiversity. PPB programs require more stable funding sources to be effective. The 2008 Farm Bill included $78 million in funding for organic agriculture research and education. That is five times the $15 million allocated by the 2002 Farm Bill but at 1% of the USDA research budget, the OFRF's position is that $78 million is far from organic agriculture's "fair-share" of nearly 4%, based on market share (OFRF, 2008b).

PPB advocates point to the need to develop new funding and public domain property models. The Organic Seed Alliance recently launched an entrepreneurial enterprise, the Family Farmers Seed Cooperative (FFSC). The goal of FFSC is to help farmers capitalize

Figure 6. Primary funding sources for PPB projects



and develop seed enterprises and provide a revenue stream for crop improvement and organic seed system development. Study participants, including farmers, plant breeders and nonprofit advocates, stress the importance of a system that provides adequate compensation for both the farmers' and plant breeders' work and investment of intellectual capital. With adequate 'pay-as-you-go' compensation, the germplasm and seed would remain fully in the public domain, facilitating its mobilization in future plant breeding efforts and varietal improvement. They purport that intellectual property regimes are exclusive and restrict the flow of germplasm, constricting the agrobiodiversity necessary for organic plant breeding. Organic principles stress maintenance of genetic and agricultural diversity. This issue has caused dissention within partnerships and at seed conferences with one concern being the difficulty of leveraging private financial investment in organic seed development in such an open source model. Others point to the need to mobilize consumer support to build the political capital to advocate for reinvestment in public breeding programs and organic farming systems.

Building Financial Capital

PPB allowed farmers to reduce and control their seed costs by managing their own seed supply. Reducing input costs is one way to build the financial capital of farmers and their farming communities. Seed selections adapted to organic farming systems, exhibiting greater disease or pest resistance, further reduce input costs and enhance income stability. Growing their own seed varieties with desirable agronomic and market traits ensured supply regardless of the variety's commercial availability. An earlier maturing variety enabled the farmer to hit the early high-priced market, translating into earlier and higher cash flows. "Inputs and outputs is still how a farm works," stated one farmer. "The key is to reduce inputs and increase outputs. Controlling the supply and quality of your seed is one avenue for doing that." ROS project reports that 36% of the farmer participants surveyed reported improved production efficiencies and crop quality as a result of growing their own seed. Developing local seed systems fosters locally-owned businesses and employment opportunities, enhancing local economies and financial capital.

Built Capital

The OSP was a contributing factor in Cornell's decision to certify 30 acres of the Freeville Research Farm in 2006, creating the Freeville Organic Research Farm. Prior to certifying this acreage, Cornell had to rely on farmer-cooperators to conduct research on certified organic systems. According to one of the members of Cornell's Organic Project Work Team (PWT), requests from researchers, a message from the organic PWT, and the OFRF's *State of the States* report all played a role in the decision.

The University of Maine also certified a portion of the Highmoor Research Farm in 2006 through a joint-decision by the farm manager and a researcher involved in organic research. On-farm organic variety trials conducted by North Dakota State University and the FBC led to decision to begin the process of certifying 8.5 acres for organic research at the Dickinson Research Center, becoming fully certified in 2007.

One of the critical needs of organic seed production is scale appropriate equipment. The OSP and the USDA Plant Genetic Resources Unit in Geneva, NY made seed processing and seed cleaning equipment available through a mobile seed processing unit mounted on a trailer. "We got to try out seed cleaning equipment, which we got to use if you hosted a field day," stated one farmer. "They brought all the equipment to our farm… The access to the equipment was really important for me to take it to a level where I'm growing 40% of my own seed. It has added a whole other level to my farm," she added.

RESULTS

Community Capitals Framework

This project analyzed how PPB partnerships contributed to increasing stocks of community capitals. The changes in the seven community capitals were qualitatively analyzed and coded to the appropriate community capital categories and are displayed in Table 5.

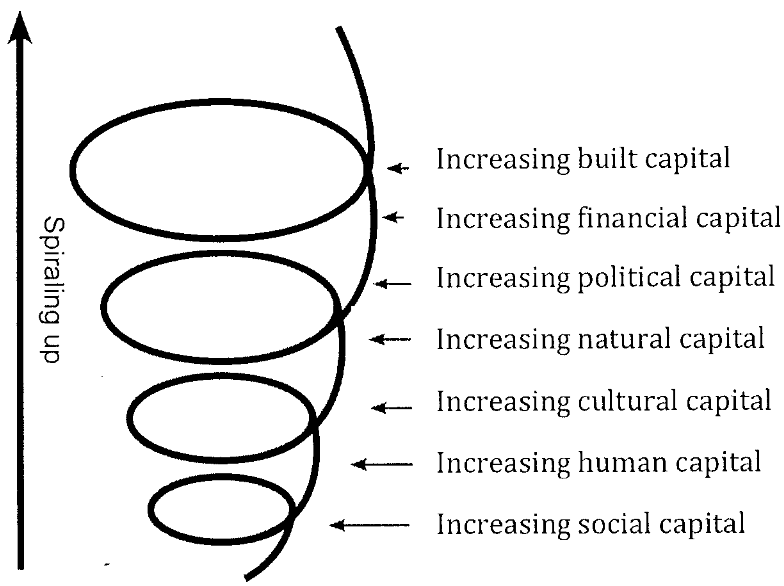
Table 5. Building of community capitals through PPB partnerships

Natural	Adoption of high-performing varieties, existing and newly developed, with suitable agronomic and market traits
	Pedigreed varieties developed within organic systems with desirable agronomic, quality and nutritional traits
	Development and distribution of genetically diverse germplasm populations
	Population varieties selected for durable resistance, organic farming systems, and organic markets
	Increased agrobiodiversity and resilience of organic farming systems
	In situ conservation of agrobiodiversity
Social	New relationships between organic farmers and scientists
	Formation of PPB partnerships
	Relationships with and validation from scientific societies
	Networking between farmer breeders, plant breeders, organic seed growers and seed companies, and the larger organic food and farming sector
	Utilizing direct consumer relationships to provide feedback on consumer preferences to the plant breeding effort
	Enhanced feedback from nature, farmers, scientific colleagues/breeders, stakeholders/clients and the public
	Increased communication, cooperation, facilitation, and planning
	Increased linkages at local, state, regional and national levels between farmers, local state and regional nonprofit organizations, universities, PPB partnerships, organic seed companies, national nonprofits and associations, scientific societies, governmental agencies, and international organizations and institutes.
	Working models of PPB partnerships
Human	Diversity of perspectives with input into the plant breeding process
	Enhanced knowledge of organic farming systems and genotype X environment interactions
	Enhanced observation, germplasm evaluation, selection, and breeding knowledge and skills among participants
	Enhanced seed production, seed saving, and seed cleaning knowledge and skills among participants
	Improved access to information sources and resource people
Cultural	Greater understanding of the cultural value/impact of seed and of stakeholder involvement in plant breeding
	New and greater appreciation for organic farming systems among LGU scientists
	Celebrating historic, regionally developed varieties and the plant breeders that developed them
	Development of regionally identifiable varieties
	Development of farmer-centric public seed systems
	Empowering farmers to take ownership of their seed supply; enhancing security and sovereignty

	Table 5. (Continued)
Political	Convening of the 2003, 2005, and 2008 Seeds & Breeds Conferences to set alternative norms for plant breeding
	Development of conclusions, policy recommendations and an action plan directed at the 2008 Farm Bill advocating for public and organic plant breeding systems
	Networking with sustainable/organic policy organizations to advocate for public/organic plant breeding systems
	Inclusion of language reading, "Developing new and improved seed varieties that are particularly suited for organic agriculture" as one of eight legislatively defined goals listed in the 2009 Organic Agriculture Research and Extension Initiative (OREI) request for applications
	Inclusion of public plant and animal breeding as a research priority in the National Organic Action Plan
Financial	Accessing federal funds through grants and congressional earmarks, and private funds through seed sales, foundations, donations and an endowment
	Entrepreneurial enterprise to help farmers capitalize and develop seed enterprises and provide a revenue stream for crop improvement and organic seed system development.
	2008 Farm Bill allocation of $78 million in funding for organic agriculture research and education
	Reduced input costs through greater disease and pest resistance and reduced seed costs
	Greater output through better agronomic performance, ability to supply early markets, and higher market quality
	Provision of employment and business opportunities through local and regional seed systems
Built	Contributing factor in the establishment and certification of Cornell's 30-acre Freeville Organic Farm
	Contributing factor in the decision to certify acreage at University of Maine's Highmoor Research Farm
	Contributing factor in the decision to certify acreage at North Dakota State University's Dickinson Research Extension Center
	Procurement and availability of seed processing and cleaning equipment through USDA - ARS, Plant Genetic Resources Unit, Geneva, NY; equipment replication by organic farmers

Existing social capital within the nonprofit organizations, built to support the development of organic farming systems, was leveraged by PPB partnerships to build bridging social capital with LGU scientists and plant breeding program. PPB partnerships created bonding social capital as the farmers combined their knowledge and wisdom with that of LGU scientists. The partnerships created new feedback loops to support the efficiency of the plant breeding process. They mobilized and invested in human capital and the building of natural capital increasing skills and enhancing knowledge and access to information. The partnerships resulted in a change in perceptions among organic farmers and scientists, creating a culture of mutual respect and collegial relationships. PPB partnerships empowered local people to manage their seed resources, developing regionally identifiable varieties and local and regional organic seed systems, creating cultural capital. PPB enhanced local control of agrobiodiversity resources and the food and farming system, further enhancing cultural capital. The partnerships developed linkages from the local to the international level, increasing their social and political capital, leveraging increased resources to support classical and organic plant breeding. PPB has created what Emery and Flora (2006) refer to as the spiraling up effect.

Figure 7. Spiraling of community capitals (Emery and Flora, 2006)



Resilience Framework and Latour's Circulatory System of Science

PPB partnerships and networks have developed highly interactive feedback loops through enhanced linkages among all four Latourian loops. PPB allows for a greater diversity of people and perspectives to be taken into consideration in the plant breeding effort, in effect democratizing the process. These feedback loops integrate ecological, economic, and social realms, facilitating the circulation of knowledge from each of the realms of sustainability.

Walker and Salt (2008) emphasize the need to acknowledge and fully understand the underlying causes of the agrobiodiversity crisis and the problems facing public plant breeding systems to enhance transformability. The Seeds and Breeds Summit meetings established a common understanding and consensus of the underlying causes, mobilizing human and social capital to actively explore and build alternative futures. PPB partnerships have resulted in the creation of local networks linked to institutions and organizations, empowering local people to sustain and breed locally adapted varieties, enhancing their agrobiodiversity resources. These results have strengthened the resilience and sustainability of food and farming systems.

Social Learning

Effective partnerships "capture both the learning about the way stakeholders are organized to respond to complex situations and the agroecological aspects" (Lightfoot, 2001, p. 133). According to project reports and publications, planning and evaluation of the PPB partnerships focused on the plant breeding objectives, completion of training objectives and participant numbers. The organizational structure for learning and the networks between partnerships and organizations is well connected, as is shown in Figures 4 and 5. The learning process, however, received insufficient attention in the different PPB evaluation processes and in plans for ongoing work.

PPB partnerships exhibit characteristics of the self-help model of community development, which is aimed at systemic change. Flora and Flora (2008) state the self-help process builds civic capacity for collective action toward a shared vision for the future" (p. 357). Self-help is about the process. There was a tendency among the PPB partnerships to slip back into the traditional LGU model of technical assistance, focusing on the most efficient way to perform a certain task; in this case providing suitable varieties to organic farming systems or providing farmers with knowledge and training. The confusion over how these partnerships agree to work together led to varying levels of frustration and satisfaction among some of the participants.

CONCLUSIONS

Triple bottom line

PPB partnerships mobilized existing natural, human and social capital, building upon those assets, and increasing all seven community capitals in the process. PPB partnerships fostered: 1) *socially-inclusive* plant-breeding and seed systems, social learning linkages from the grassroots level to the international level, and highly responsive feedback loops to augment the plant breeding process; 2) *ecological health* and resilience through greater agrobiodiversity and adaptability; 3) *economic vitality* through a) the means to reduce input costs and boost outputs, b) a highly motivated, networked, and politically active stakeholder group to advocate for increased funding of public plant breeding systems, c) the enhanced viability of existing organic seed companies, and d) the opportunity for growth of local and regional seed systems. PPB partnerships directly address the triple bottom line of sustainability—social inclusion, ecological health, and a vital economy.

The interrelationships between food production, decreasing soil health and fresh water resources, coupled with increasing population, energy costs, greenhouse gas emissions, and climate instability make adaptive change an agroecological and socio-economic imperative. The need for resilience in the face of these challenges requires a multi-functional system of agriculture that produces rather than consumes ecosystem services.

PPB partnerships provide for the co-evolution of the agroecological and socio-economic aspects of agroecosystems by supplying and integrating a diversity of both natural and human capital supported by strong social and cultural capital. PPB in effect democratizes the plant breeding process, incorporating the feedback circulating through all of the Latourian loops "allowing all knowledge to be applied to the problem," (Wilson, 2009, p. xix). This provides the mechanisms necessary for a responsive and resilient system capable of discerning and adapting to changes in both the agroecological and socio-economic environment.

Social Learning

The integrated agroecological and socio-economic aspects of PPB partnerships necessitate the involvement of farmers with interdisciplinary scientific partners including plant pathologists, entomologists, agronomists, horticulturalists, climatologists, ethnobotanists, agricultural economists or social scientists. PPB partnerships require and facilitate systems level analysis versus the reductionist approach dominant in agriculture.

The same systems level thinking that PPB partnerships apply to the agroecological aspects must be applied to the social learning aspects of the partnerships. The process of PPB is not just about plant breeding and providing suitable varieties for organic farming systems; it is about community development. As such PPB should focus on building existing community capitals, utilizing an appreciative inquiry approach. Flora and Flora (2008) describe appreciative inquiry as a dynamic, asset-based approach to planning, strategizing, and monitoring the change process. The protagonists of the development of local and regional plant varieties must be local people. PPB partnerships must develop learning instruments, agree on operational processes, and incorporate all of the phases of the learning process into their work.

Röling and Jiggins (1998) state that moving toward a more ecologically sound agriculture "requires learning new roles across a wide range of actors," (p. 293) including farmers, researchers, research institutions, consumers, and policymakers. It requires 'discovery learning' and the 'social construction of the ecosystem,' engaging people in experimentation, observation, and measurement… creating tools for discovery learning" (Ibid., pp. 292-293). To that end it is crucial to bring participants from the various PPB partnerships together at the national level to learn from each other's experiences and further the development of the organizational learning structure and the social learning instruments and process of PPB. The results will provide for a more internally inclusive and externally integrative learning process and better evaluation, documentation, and transparency of impact; this is of vital interest to decision-makers and funders and is crucial to the development of the social, political and financial capital necessary to support PPB.

In order to efficiently mobilize natural capital to address the plant breeding needs of organic farming systems and the agroecological and socio-economic crisis we find ourselves in, it is necessary to reprioritize breeding goals and reconfigure plant breeding models for agroecological systems of agriculture. It is critical to mobilize feedback loops and the social and political capital present within the organic community to advocate for public plant breeding systems, PPB and open-source seed systems.

Organic agricultural systems must be based upon genetically diverse varieties and populations bred within agroecological systems, featuring crop rotation, multi-cropping, companion planting and polycultures. The seed must be held in the public domain resulting in inclusive seed and plant breeding systems, and open-source access. Community capitals are enhanced, including locally bred diversity, local knowledge, local and regional seed systems, public plant breeding programs, adaptability and resilience, food sovereignty and food security.

Nabhan (2009) states "it is the social, economic and political access to seed diversity at critical moments that can make or break a community's means of achieving food security" (p. 192). Now is the critical moment.

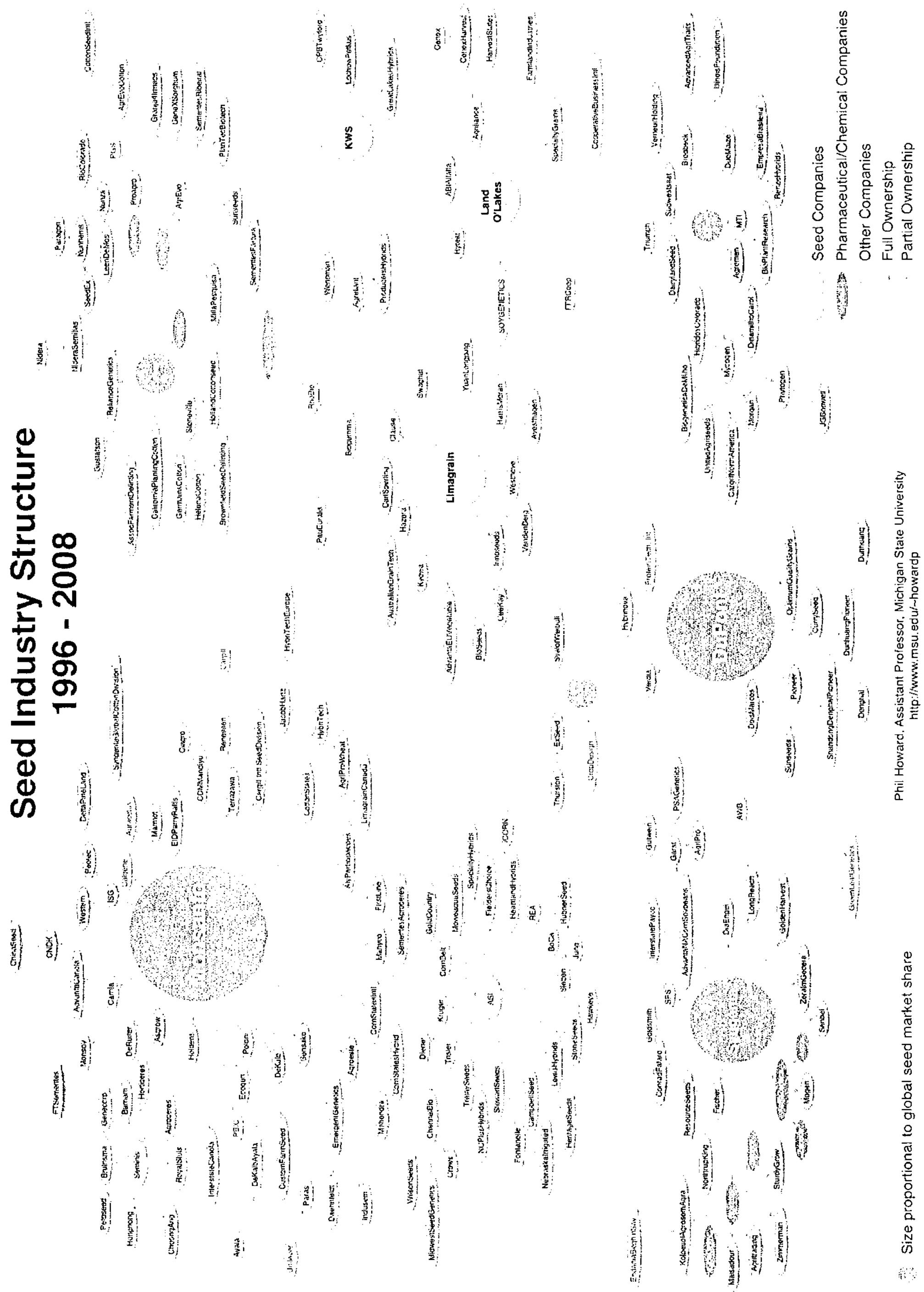
FURTHER RESEARCH

Further research is needed on:

- The efficiency of PPB in terms of costs, use of resources, development time, varietal performance, seed dispersion and adoption, and distribution channels.
- Learning instruments for clarifying services required, partnership roles, responsibilities, attributes, and values of PPB partnerships.
- Indicators and scoring instruments reflecting agroecological and socio-economic performance and impact of PPB partnerships.
- Policies and procedures that provide for open access germplasm and seed systems, including farmers' and breeders' rights to exchange and improve germplasm and seed, and the farmers' right to save and sell seed.
- The co-evolution of PPB, adaptive organic farming systems, markets, and cultural value of food and seed
- Genotype x environment interactions in adaptive organic farming systems, ie.) varietal response to soil microbiology, crop rotation, companion planting
- Mapping of the organic seed sector.

APPENDIX A.

Figure 8. Consolidation in the Seed Industry



(Howard, 2009)

APPENDIX B. Table 4. PPB Projects and Breeding Priorities

NATURAL CAPITAL	Project Initiation
Organic Seed Alliance is a strong advocate of PPB. OSA places the emphasis on the need to develop collaborative and collegial partnerships between plant breeders and farmers, developing varieties adapted to organic farming systems through evolutionary plant breeding. To that end, they provide training programs for farmers on the fundamentals of plant breeding. The emphasis is on mobilizing social capital with a strong secondary emphasis on the co-evolutionary building of human and natural capital.	
OP zucchini of a plant type with open foliage for easier harvest, a good angle for fruit set, a low degree of petiole spines, dark green, cylindrical, and a good length to diameter ratio for uniform harvest.	2003
OP Red Curly Kale-- (red kale X brussels sprouts) mass selection for tall, red kale with strong stalks, cold hardiness, good winter productivity, medium-savoyed leaves, tender, good flavor, and disease resistance. After eight generations of selection the farmer partnered with OSA in 2004 to develop a commercial quality variety.	2004
OP Winter Carrot-- good flavor, shape with tall and wide bushy tops to shade out weeds; ability to hold its top and keep a harvestable root with few root hairs over winter, making it possible to pull roots into April.	2005
OP Sweet Corn-- vigorous germination, cold tolerance, smut and leaf blight resistance, taste, sweetness, good cob pack and fill, adaptation to organic farming systems	2007
Farm Breeder Club emphasized the development of a PPB model linking plant breeders, farmers, and end-users as co-learners and co-teachers with the goals of: 1) providing varieties bred for and adapted to organic farming and marketing systems, and 2) advocating for public plant breeding systems at the university and federal level. The emphasis was on mobilizing social and human capital to build natural and political capital.	
Organic variety trials and seed increases of small grains, heritage wheat varieties, and an ancient grain, emmer, with natural selection for adaptation to organic environments.	2001
FBC-Dylan, a hard red spring wheat with increased scab tolerance given to the FBC in 2005 by a retired plant breeder, Matt Kolding. Entered in organic variety trials, made seed increases, and released by FBC as a public variety in 2007.	2005
Organic Seed Project focused on mobilizing existing germplasm developed at Cornell, exhibiting powdery mildew resistance and incorporating it into varietal populations with other agronomic and quality traits of interest to organic farmers. The most efficient means for doing so, given Cornell's lack of access to organic farming environments, was to partner with organic farmers in a PPB relationship. They partnered with NOFA-NY to establish relationships with farmers. The OSP also provided training to organic farmers in plant breeding methods. OSP emphasized mobilizing existing natural capital and building bridging social capital to enhance natural capital.	
OP Broccoli: Random mating with selection against downy mildew with heat tolerance; selections made from a breeding population supplied by Oregon State; improved but not fully stable; anticipate three or more varietal releases.	2001
Disease Resistant Early Bell Pepper: several stable lines including one that is registered with the USDA and is currently available from Fedco Seeds as "Peacework." An additional line is in the process of being named and licensed.	2002

Table 4. (Continued)	
Improved Pruden's Purple Tomato: a continuation of a project started by the Restoring Our Seed Project; improved but not fully stable.	2003
Leafhopper Resistant Potato for Organic Systems: Potato variety (King Harry) officially released and commercially available as certified organic seed.	2004
Improved Costata Romanesca Squash: improved powdery mildew resistance and compact bush plant habit retaining original taste of the heirloom parent; also have lines with novel colors.	2004
Improved Heirloom Melons: powdery mildew resistant, high yielding melon, maintaining the best traits of the heirloom parents; several improved and stable lines of both cantaloupe and honey dew types.	2004
Improved Heirloom Cucumbers: powdery mildew resistant cucumber with initial crosses made between heirlooms (Boothby's Blonde X Cornell's Marketmore 97); 3 stable lines and one registered variety, named "Platinum".	2004
Overall, between the eight projects OSP generated 23 advanced breeding populations. This included 6 lines of pepper, 2 lines of broccoli, 3 lines of cucumbers, 5 lines of squash, 1 line of tomato, and 6 lines of melon.	
Restoring Our Seed focused on providing a training program, building human capital and empowering farmers to build their natural capital. ROS partnered with university scientists, who participated largely in a consultative/training role to enhance farmers' plant breeding knowledge and skills, empowering farmers. Squash, tomatoes, cucumbers, and radishes were chosen for their diverse breeding morphology to demonstrate different plant breeding methods. The breeding work on a disease resistant cucumber, for example, although highly participatory, was described as a demonstration/training project. The emphasis was on mobilizing existing human and social capital, building human and cultural capital, empowering farmers to enhance natural capital.	
Even' Star Cold-Hardy Winter Greens: (Brett Grohsgal) developed lines of winter-hardy salad greens over the past fifteen years-- arugula, thick-stem mustard, tatsoi, smooth kale, collards, tenderleaf and segregating mustards.	1988
Winter-Hardy Greens Gene-Pools: over-wintering greens (in low tunnels) of diverse brassica gene pools: mizuna/tatsoi cross, maruba/mizuna/tatsoi cross, and 7 mustards selected for winter hardiness, flavor and texture since 1999.	1999
Pruden's Purple- An early blight resistant, thick-skinned, firm, early tomato producing good market yields with an attractive shape; not yet fully stable.	2003
Brandy Rose' (Brandywine x Rose de Berne)--Brandywine is large and tender with rich flavor. Rose de Berne is almost blemish-free, pink translucent skin, rose-pink flesh, flavorful and juicy. Selected best qualities of each.	2003
Wonder Pickle-- (Conquest x Clinton x Wautoma) Selected for plant health, reduced foliar diseases, dark color, good yield over the season, and flavor.	2003
Potato Dance - A combination of Blossom (the maternal plant) with Caribe, Island Sunshine, Prince Hairy, Green Mountain, Purple Peruvian. Selected for resistance to Colorado potato beetle and flavor.	2004
Winter Luxury Pumpkin-- Selected for storage and stem strength.	2004
Dancing Greens-- cross-pollinating varieties grown in a mixture selecting for unique salad greens. Mizpoona (Mizuna x Tatsoi), Purple Mizuna <from wildgardenseed.com>, Scarlet Mizpoona (Mizuna x Tatsoi x Scarlet Ohno Turnip).	2004
Dancing Kales: 30 kales over-wintered with no protection; surviving plants go to seed and cross. Selected for diverse gene pool of cold hardy kales with good flavor.	2004

Table 4. (Continued)	
Northern Grain Growers gathered together to exchange ideas and network with each other, providing camaraderie. They conducted wheat variety trials to identify germplasm suited to their more humid environment. The farmers partnered with an extension specialist in Vermont. After receiving hands-on training in wheat pollination techniques with Dr. Stephan Jones at Washington State University and trying their hands at it, they partnered with Dr. Jones to make the crosses. (There are no public wheat breeders in the NE Region). The F1s were taken back to Vermont for selection and adaptation to their organic environments. The project focused on mobilizing social capital and building human capital to enhance natural capital.	
19 wheat crosses under evaluation in organic environments for inclusion in the development of a wheat population	2004
Washington State Participatory Wheat Breeding Project project developed partnerships between farmers and plant breeders to disperse genetically diverse populations of wheat, providing for adaptability to organic farming systems. The emphasis was on mobilizing social and natural capital to enhance natural capital.	
Breeding wheat for stripe leaf resistance, tolerance to lower temperatures, and specific adaptation to the farm's growing conditions, including low organic content and low rainfall (7-9 inches annual rainfall).	2003
Michael Fields Agricultural Institute/USDA Agriculture Research Service/Practical Farmers of Iowa partnership formed through a progression of networking relationships. Farmers approached MFAI with their interest in open pollinated corn varieties for organic farming systems and PPB. This initial partnership subsequently partnered with the USDA-ARS Research Station at Iowa State University exchanging germplasm, data, and field test locations. PFI joined the partnership to provide training and outreach to farmers interested in PPB and to other organizations, and organize field days. The emphasis was on mobilizing social and natural capital, building human capital to enhance natural capital.	
A high-lysine, high-oil, high-vitamin E, high carotinoid OP corn.	2000
OP corn with superior feeding value; high protein, high carotenoid content, sweet, tender stalks that cows will eat.	2000
OP white, yellow, red, and blue field corn varieties with quality traits suitable to niche markets.	2000
OP populations of large-seed white flour corn, adapted to organic systems and different maturity dates.	2000
Food-grade, milling-quality, high protein, OP corn for a premium market; kernels more orange than yellow, indicating a high horny endosperm and low starch content; utilizes soil nutrients more efficiently; has firm, straight, stalk, down-turned ears as it ripens, with a loosening husk.	2002
OP corn with greater weed suppression and adaptation to sustainable and organic growing environments.	2004
Corn varieties high in the essential amino acids, methionine and lysine, needed in feed rations.	2008
The incorporation of genes that make OP corn non-receptive to foreign or transgenic pollen.	2008
White flour corn with good nutrition and taste; makes good tortillas.	2009

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